ENEE 303H Final Solutions 2013 RWN 12/14/13b

#1. a) If voltage @ C wrt gnd > $|V_{TO}|$ & < $V_{DD}-|V_{TO}|$ both transistors would be ohmic; assume it is the case

$$i_{D_n} = \frac{KP}{2}\frac{W}{L}\{(V_{DD}-|V_{TO}|)V_C-\frac{1}{2}V_C^2\} = i_{S_p} = \frac{KP}{2}\frac{W}{L}\{(V_{DD}-0-|V_{TO}|)(V_{DD}-V_C)-\frac{1}{2}(V_{DD}-V_C)^2\}$$

$$\Rightarrow V_{DD}V_C - V_C - \frac{1}{2}V_C^2 = V_{DD}^2 - V_{DD}V_C - V_{DD} + V_C - \frac{1}{2}V_{DD}^2 + \frac{1}{2}\cdot 2V_{DD}V_C - \frac{1}{2}V_C^2 \Rightarrow \text{solve for } V_C$$

$$\Rightarrow 0 = \frac{1}{2}V_{DD}^2 - V_{DD} - (V_{DD}-2)V_C \Rightarrow$$

$$V_C = \frac{V_{DD}(\frac{1}{2}V_{DD}-1)}{V_{DD}-2} = \frac{9(4.5-1)}{7} = 4.5V = V_C$$

since $4.5 = V_C = V_{DS_n} < V_{GS_n} - V_{TO_n} = 8$ M_n is ohmic

& $4.5 = V_{DD} - V_C = V_{SD_p} < V_{SG_p} - |V_{TO_p}| = V_{DD} - 0 - 1 = 8$, M_p is ohmic

so the assumption is valid & $V_C = V_{DD}/2$ [not a good logic device]

b) By symmetry $V_C = V_{DD}/2$ when $A=1, B=0$.

For the other 2 cases the circuit is an inverter, so

$A=0=B \Rightarrow C=1$; $A=1=B \Rightarrow C=0$

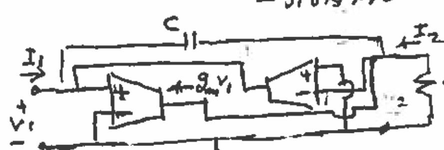
#2. For the given circuit, $V_{GS}=0$, so the law is

$$I = I_S(1-e^{-V/V_T})$$

a) $g = I_S((-1)(-1/V_T))e^{-V/V_T} = \frac{I_S}{V_T}\cdot e^{-V/V_T} = g$

b) $r = \frac{1}{g}\Big|_{V=1/2} = \frac{0.026}{10^{-18}}\cdot e^{\frac{1}{2\times 0.026}} = 0.026\times 10^{18}\times 2.248\times 10^{8}$

$= 5.845\times 10^{24}\,\Omega$ $\Rightarrow$ a very large small signal R

#3. a) 

; $\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} I_1 \\ -GV_2 \end{bmatrix} = \begin{bmatrix} Cs & -Cs+g_m \\ -Cs-g_m & Cs \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$

from second row $-GV_2 - CsV_2 = (-Cs-g_m)V_1 \Rightarrow \frac{V_2}{V_1} = \frac{Cs+g_m}{Cs+G} = \frac{s+g_m/C}{s+G/C}$

b) zero: $s_0 = -g_m/C$, pole: $s_p = -G/C$

#4. $I_C = \beta I_B = 2\times 10^2 \times 10^{-5} = 2\times 10^{-3}A = I_S = \frac{KP}{2}\frac{W}{L}(V_{SG}-|V_{TO}|)^2 \Rightarrow V_{SG} = |V_{TO}| + \frac{2L/W}{KP}I_S$

assume Mout in saturation $\Rightarrow I_{S\,Mout} = 2(W/L)_{Min}\cdot I_C = 2\times 1\times 2\times 10^{-3}A$

$\Rightarrow V_{R_L} = 1\times 4\times 10^{-3}V = 4\,mV$

(check assumption: $V_{SG_{Mout}} - |V_{TO}| = \frac{2(1/2)}{KP}I_S = \frac{2\times 10^{-3}}{3\times 10^{-4}} = 6.67V < V_{DD} - V_{R_L} \approx 8.996$

$\therefore$ $V_{R_L} = 4\,mV$